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A Study of Robotics and its Emerging Applications

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ABSTRACT

Robotics is one of the fastest-growing technologies, integrating artificial intelligence (AI), machine learning, computer vision, sensors, and automation to improve efficiency, accuracy, and safety across various industries. Modern robotic systems are designed to perform complex, repetitive, and hazardous tasks with minimal human intervention, making them an essential part of technological advancement. This paper presents an overview of four major application areas of robotics: underwater, medical and healthcare, humanoid, and agricultural robotics. Underwater robots are used for ocean exploration, marine research, and inspection of underwater structures. Medical robots support surgery, rehabilitation, patient care, and hospital logistics. Humanoid robots are designed to interact with people and are widely used in healthcare, education, customer service, and industries. Agricultural robots assist in farming operations such as crop monitoring, precision spraying, irrigation, and harvesting, helping to improve productivity and reduce labour requirements. The paper also discusses the key technologies, advantages, challenges, and future scope of robotics. It highlights how intelligent robotic systems are expected to play an important role in scientific research and healthcare.

Keywords: Robotics; Emerging Applications; Underwater Robotics; Medical and Healthcare Robotics; Humanoid Robotics; Agriculture Robotics; Artificial Intelligence; Autonomous Systems; Automation; Robot Technology

INTRODUCTION

Robotics is an important branch of engineering and technology that deals with the design, development, and operation of robots. Modern robots combine mechanical systems, electronics, sensors, actuators, computer programming, and Artificial Intelligence (AI) to perform tasks automatically with accuracy and efficiency. Recent research focuses on improving robot intelligence, autonomous operation, navigation, sensing, and human–robot interaction.

In this study, four important areas of robotics are considered: Underwater Robotics, Medical and Healthcare Robotics, Humanoid Robotics, and Agricultural Robotics.

Underwater robots are designed to perform tasks such as ocean exploration, marine research, underwater inspection, and search operations. They use cameras, sonar, and sensors to collect information and navigate underwater. These robots can work in deep-water areas where human access is difficult or risky. They are useful in research and industries, but face challenges such as limited battery power, communication difficulties, and high water pressure. Underwater robotics plays an important role in modern marine technology.

Medical and healthcare robots are designed to assist doctors, nurses, and patients in various medical activities. They are used in surgery, diagnosis, rehabilitation, patient monitoring, medicine delivery, and elderly care. These robots use sensors, cameras, and control systems to perform tasks with high accuracy and safety. They help reduce the workload of healthcare workers and improve the efficiency of medical services. However, their development involves challenges such as high cost, safety, reliability, and the need for skilled operators. With continuous technological development, medical robots are becoming an important part of modern healthcare.

Humanoid robotics focuses on designing robots with human-like body structures, movements, and interaction abilities. These robots use sensors, cameras, actuators, and artificial intelligence to perform tasks such as walking, object handling, communication, and assisting humans. They are used in industries, hospitals, education, and public services. Although they offer many benefits, challenges such as high cost, energy consumption, balance, and safety remain. Humanoid robotics has great potential in future technology and human assistance.

Agricultural robotics uses robots, sensors, artificial intelligence, and automation to improve farming activities. These robots are used for planting, weeding, spraying, crop monitoring, and harvesting. They help reduce manual labour, save time, and increase productivity. Although challenges such as high cost and difficult field conditions remain, agricultural robotics has great potential to make farming more efficient and sustainable.

METHODOLOGY

The study was carried out by reviewing and comparing selected research papers on four major areas of robotics: underwater, medical and healthcare, humanoid, and agricultural robotics. Different robotic systems were studied based on their design, mechanical structure, sensors, actuators, control systems, navigation, artificial intelligence, and autonomous operation.

The study on underwater robotics and comparing their design, propulsion, sensors, control systems, navigation, communication, autonomous operation, and testing methods. Different underwater robotic systems, including AUVs, ROVs, bio-inspired robots, flexible robots, and UUVs, were considered. The studies used mathematical modelling, simulation, prototype development, image processing, artificial intelligence, and laboratory and open-water experiments. The developed systems were evaluated based on movement, manoeuvrability, navigation, object detection, control accuracy, communication, energy consumption, and autonomous performance.

The study also considered the use of different sensors and cameras for underwater perception and data collection. Image-processing and AI techniques were studied for identifying and detecting underwater objects. Simulation tools were used before practical testing to check robot movement and control performance.

Finally, the experimental results from different studies were compared to understand the advantages, limitations, applications, and future possibilities of underwater robots. This helped identify how improvements in autonomous navigation, flexible propulsion, sensing, communication, and intelligent control can support underwater exploration, inspection, monitoring, and other marine applications [1]–[9].

The study on medical and healthcare robotics and comparing their design, robotic systems, sensors, control systems, navigation, human–robot interaction, autonomous operation, and testing methods. Different medical robotic systems, including surgical robots, rehabilitation robots, diagnostic robots, patient-assistance robots, and medicine-delivery robots, were considered. The studies used mathematical modelling, simulation, prototype development, image processing, artificial intelligence, and laboratory and clinical experiments. The developed systems were evaluated based on movement, accuracy, safety, control performance, object or patient detection, human–robot interaction, energy consumption, and autonomous performance.

The study also considered the use of different sensors, cameras, imaging systems, and other technologies for medical sensing and data collection. Image-processing and AI techniques were studied for detecting medical conditions, identifying objects, assisting surgeons, and monitoring patients. Simulation tools were used before practical testing to check robot movement, control performance, and safety.

Finally, the experimental results from different studies were compared to understand the advantages, limitations, applications, and future possibilities of medical and healthcare robots. This helped identify how improvements in surgical accuracy, rehabilitation, sensing, artificial intelligence, autonomous operation, and human–robot interaction can contribute to safer and more efficient healthcare [10]–[19].

The study on humanoid robotics, with emphasis on robot design, mechanical structure, actuation, sensing, locomotion, motion planning, control systems, artificial intelligence, human–robot interaction, and autonomous operation. Different humanoid robotic platforms, including bipedal robots, service humanoids, industrial humanoids, and research platforms, were considered. The reviewed studies used mathematical modelling, simulation, prototype development, computer vision, machine learning, reinforcement learning, and experimental testing to develop and evaluate humanoid robotic systems.

Humanoid robots were evaluated based on locomotion, balance, manipulation, sensing, control accuracy, energy efficiency, and human–robot interaction. Simulation and AI-based techniques were used to test robot dynamics, motion planning, perception, decision-making, and control before real-world implementation.

Finally, The results of different studies were compared to identify the advantages, limitations, applications, and future scope of humanoid robotics. The comparison focused on intelligent control, sensing, actuation, motion planning, autonomous decision-making, and human–robot interaction. The findings highlight the potential for developing safer, efficient, adaptable, and autonomous humanoid robots for various real-world applications [20]–[30].

Agricultural robotics mainly uses a combination of robotic systems, sensors, cameras, image processing, artificial intelligence, and autonomous navigation to perform farming tasks. In these methods, images and field information are collected using cameras and other sensors. The collected data is then processed to identify crops, weeds, plants, or other objects in the field. Deep learning and computer vision techniques are used for detection and classification, while navigation methods help the robot move through crop rows and avoid obstacles. Based on the detected information, the robot can perform tasks such as weed removal, precision spraying, crop monitoring, planting, harvesting, and other agricultural operations. Different robotic platforms and tool attachments are also used depending on the required task. The performance of these systems is evaluated through simulation, laboratory testing, and field experiments to check their accuracy, movement, efficiency, and practical operation [31]–[40].

1. UNDERWATER ROBOTICS

1.1 Underwater Robot

An underwater robot is a robotic machine designed to operate underwater and perform tasks such as ocean exploration, marine research, underwater inspection, and search operations. It uses sensors, cameras, sonar, motors, and control systems to move, collect information, and perform tasks in underwater environments where human access is difficult or risky.

1.2 Types of Underwater robots

1.2.1 Underwater Object-Detection System – UWCycleGAN + YOLOv4

This system is used to detect objects in underwater images. UWCycleGAN creates realistic underwater images from normal images, and YOLOv4 is used to identify objects such as bolts, nuts, flanges, anodes, and pipelines. It can be useful for automatic underwater inspection.

1.2.2 Underwater Vehicle–Manipulator System (UVMS)

This system combines an underwater vehicle with robotic manipulators (robotic arms). Two underwater vehicles with six-link Orion 7R manipulators were studied for moving objects along a required path. The main purpose is to achieve accurate underwater manipulation and object handling.

1.2.3 BlueROV2 – ROV

BlueROV2 is a Remotely Operated Vehicle (ROV) controlled by a human operator. The operator's head and body movements are converted into commands for the robot. Its camera provides underwater video to the operator, making it useful for underwater inspection and observation.

1.2.4 MMBAUV – Bio-Inspired Robot

MMBAUV is a fish-inspired autonomous underwater robot. It has a modular body, flexible joints, and a tail fin that produces swimming motion similar to a fish. It was tested for swimming, thrust generation, and manoeuvrability.

1.2.5 Aquabot – Cuttlefish-Inspired AUV

Aquabot is an autonomous underwater robot inspired by the swimming motion of a cuttlefish. Its fins provide propulsion, while a variable buoyancy system helps it control its depth. It also uses a camera and AI-based YOLOv5 to detect underwater objects.

1.2.6 Slender and Flexible Snake-like Robot

This robot is inspired by the movement of snakes. It has flexible joints that allow it to bend and move through narrow underwater areas. It uses sensors such as pressure, temperature, camera, and ultrasonic sensors for inspection, sensing, and obstacle avoidance.

1.2.7 MeCO AUV

MeCO is a low-cost, open-source Autonomous Underwater Vehicle (AUV). It has five thrusters that provide six-degree-of-freedom movement. It uses cameras, sensors, onboard computing, ROS 2, and AI-based vision systems for autonomous navigation, target following, and underwater object detection.

1.2.8 Miniature Underwater Robot (MUR)

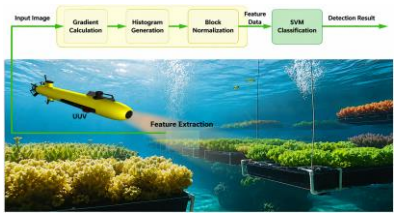
The Miniature Underwater Robot (MUR) is a small, modular and open-source underwater robot designed for aquatic research and exploration. It can carry different sensors and cameras and can be adapted for different underwater tasks such as marine research, environmental monitoring, and exploration.

1.2.9 Autonomous UUV Fleet

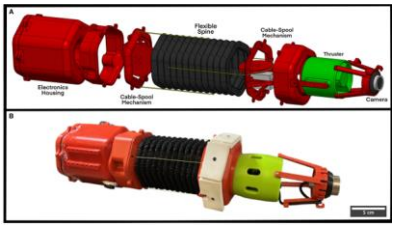
This Robot consists of a group of Unmanned Underwater Vehicles (UUVs) rather than one single robot. The UUVs can communicate with each other, move autonomously, monitor underwater areas, and detect objects. The system is designed for marine missions and underwater farming applications.

1.2.10 DRAGON 3D

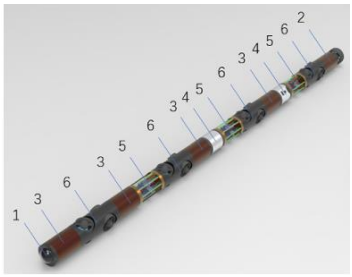
DRAGON 3D is a soft and flexible underwater robot. It has a flexible spine that can bend in three dimensions, allowing it to change direction and perform agile movements. It can perform circular motion, figure-eight movement, slalom, diving, and depth changes.



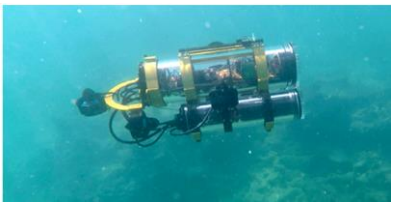
(a) Autonomous UUV fleet



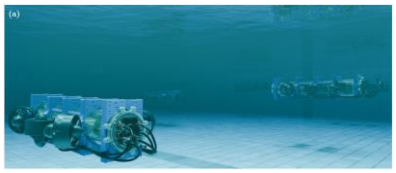
(b) DRAGON 3D



(c) Slender and flexible robot



(d) MeCO AUV



(e) Miniature Underwater Robot (MUR)



(f) Aquabot – cuttlefish-inspired AUV

Fig. 1. Examples of underwater robots

1.3 Results and Discussion

1.3.1 Robot Design

The different types of underwater robots were developed for different purposes. Some robots have a normal rigid body with thrusters, while others use flexible or bio-inspired designs. For example, MMBAUV uses a fish-like design, Aquabot is inspired by a cuttlefish, and the snake-like robot uses flexible joints. MeCO has a modular body, which makes it easier to change or add components.

1.3.2 Propulsion and Movement

The robots use different methods to move underwater. Most of them use motors and thrusters, while bio-inspired robots use fins or body movement. DRAGON 3D uses a single thruster along with a flexible body for movement. These different methods help the robots move, turn, dive, and change their direction underwater.

1.3.3 Sensors

Sensors are used to collect information about the robot and its surroundings. The papers mention cameras, IMUs, depth sensors, pressure sensors, ultrasonic sensors, and other sensors. Cameras are mainly used to see and detect underwater objects, while IMU and depth sensors help in understanding the robot's movement and depth.

1.3.4 Navigation and Control

Navigation is needed to make the robot move in the required direction. The robots use sensor information and control systems to maintain their movement and follow a planned path. Some of the robots can work autonomously, while others can be controlled by an operator. Aquabot and MeCO are examples where autonomous control is used for underwater operation.

1.3.5 AI and Computer Vision

AI is mainly used for detecting objects and helping the robot understand underwater images. Aquabot uses YOLOv5 for object detection, while the UWCycleGAN study uses YOLOv4 with generated underwater images. MeCO also uses vision-based methods for object detection and navigation.

1.3.6 Communication

Communication is difficult underwater compared with normal environments. Different methods were used in the papers. MMBAUV uses Bluetooth communication, while DRAGON 3D and the UUV fleet use acoustic communication. These methods help in sending information or commands during underwater operation.

1.3.7 Testing

The robots were tested using both simulation and real experiments. MeCO was tested in closed water, freshwater, and seawater. DRAGON 3D was first tested in simulation and later in a swimming pool and open-water conditions. These tests helped the researchers check movement, control, and overall performance.

1.3.8 Applications

The robots studied in these papers can be used for different underwater activities. These include underwater exploration, inspection, marine research, object detection, environmental monitoring, and search or monitoring missions. Some robots can also be used in narrow areas where normal underwater vehicles may have difficulty moving.

1.3.9 Recent Developments of Underwater Robots

Recent developments in underwater robotics focus on autonomous operation, AI, advanced sensors, flexible designs, and improved communication. AI and deep learning are used for object detection, navigation, obstacle avoidance, and sensor data processing. Multi-robot systems are also being developed for underwater missions.

Bio-inspired and flexible robots, such as fish- and cuttlefish-inspired robots, provide better movement and maneuverability in complex areas. Low-cost and open-source robots with cameras, IMUs, depth sensors, DVLs, and onboard computers are also becoming more common for research and education.

1.3.10 Future scope

In the future, the development of underwater robots will mainly focus on expanding their applications and improving their capabilities. In defence, they may be developed for underwater surveillance, security monitoring, mine detection, and search operations. In oil and gas industries, future robots can be improved for pipeline inspection, offshore platform monitoring, and underwater maintenance. In marine research, they can explore deeper and more difficult areas and collect environmental data. They can also be further developed for search and rescue, underwater construction, cable inspection, environmental monitoring, and marine-life observation. Overall, future developments will make underwater robots more suitable for long-duration, autonomous, and difficult underwater applications.

2. MEDICAL AND HEALTHCARE ROBOTICS

2.1 Medical and health care robot

A medical and healthcare robot is a robotic machine designed to assist doctors, nurses, and patients in medical activities. It is used for surgery, diagnosis, rehabilitation, patient monitoring, medicine delivery, and elderly care. These robots use sensors, cameras, actuators, and control systems to perform tasks with high accuracy and safety.

2.2 Types of Medical and Healthcare robotics

2.2.1 Surgical Robot

Surgical robots are used to assist doctors during medical operations. They provide precise and controlled movements, which can be useful during complex surgeries. These systems may include robotic arms, cameras, and surgical instruments. They can help improve accuracy and reduce unnecessary movement during surgery.

2.2.2 Rehabilitation Robot

Rehabilitation robots are designed to help patients recover their movement after injuries, surgery, or neurological problems. They can assist patients in performing repeated exercises for the arms, legs, or other body parts. Sensors are used to monitor the patient's movement and provide suitable assistance during rehabilitation.

2.2.3 Diagnostic Robot

Diagnostic robots are used to assist healthcare professionals in examining and diagnosing patients. They can use cameras, sensors, and medical imaging systems to collect information from the patient. These robots can support doctors in detecting abnormalities and obtaining accurate medical information.

2.2.4 Patient monitoring Robot

Patient-monitoring robots are designed to continuously monitor important patient information. They can use sensors and cameras to observe parameters such as movement, body condition, and other patient-related information. The collected information can be provided to doctors or nurses for further monitoring and care.

2.2.5 Medicine Delivery robot

Medicine-delivery robots are used in hospitals to transport medicines and other medical materials from one location to another. These robots can reduce the workload of healthcare workers and help deliver medicines at the required time. They can also be designed to navigate through hospital corridors automatically.

2.2.6 Controlled gyroscopic robot

Controlled Gyroscope Robots are developed to provide stability and control during movement. They use a rotating gyroscope to maintain balance and reduce unwanted tilting or vibration. These robots can be useful in applications such as mobile robots, vehicles, drones, and other systems that require accurate motion and stability. They help improve the safety, balance, and performance of robotic systems.

2.2.7 Cardiac catheterization robot

Robotic-assisted catheter systems are used to help doctors perform heart and blood-vessel treatments. These robots help control and guide catheters accurately inside the patient's body. They can improve accuracy, reduce doctor workload, and support safer procedures.

2.2.8 Plug and Train Robot (PLUTO)

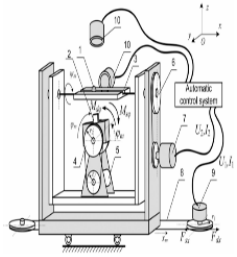
PLUTO (plug-and-Train Robot) is a robotic rehabilitation system used to help stroke patients recover hand and wrist movements. It helps patients perform different exercises such as wrist flexion-extension, wrist abduction-adduction, pro-supination, and knob manipulation. The system can support home-based rehabilitation, improve hand function, and help patients perform daily activities more easily

2.2.9 Spinal phantom robot

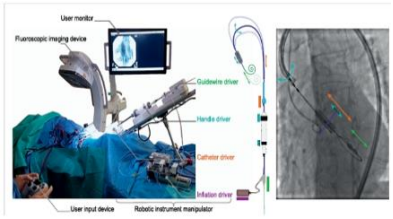
Robotic system for lumbar puncture and epidural steroid injection is a robot-assisted medical system that helps doctors accurately guide and position a needle into the required tissue layer. It uses bio-impedance signals and a Bayesian Neural Network (BNN) to identify tissues such as skin, fat, ligament, and cerebrospinal fluid (CSF), and can automatically stop the needle when the target tissue is reached.

2.2.10 3D flexible endoscope robot

flexible endoscope robot is a robotic system that controls a flexible endoscope to help doctors examine and treat the inside of the human body. It provides accurate movement, better control, and easier navigation through narrow and curved body passages.



(a) Controlled gyroscopic robot



(b) Cardiac catheterization robot



(c) Plug and Train Robot (PLUTO)



(d) Spinal phantom robot



(e) 3D flexible endoscope robot

Fig. 2. Examples of medical and healthcare robots

2.3 Results and Discussion

2.3.1 Robot Design

Medical and healthcare robots are developed in different designs depending on the type of medical task. Some robots have robotic arms for surgery, while others are designed for rehabilitation, patient assistance, medicine delivery, or medical examination. Surgical robots are designed to provide accurate movement of medical instruments. Rehabilitation robots are designed to support the movement of the patient's arms, hands, or legs.

2.3.2 Propulsion and Movement

Medical robots use motors, actuators, robotic joints, and other mechanisms to perform controlled movements. Surgical robots provide precise movement of surgical instruments, while rehabilitation robots help patients perform repeated exercises. Some assistive robots are also designed to move around hospitals or homes to provide support to patients and elderly people.

2.3.3 Sensors

Sensors are important for collecting information about the patient, robot, and surrounding environment. Medical robots may use cameras, force sensors, position sensors, pressure sensors, motion sensors, and depth sensors. These sensors help the robot detect movement, measure forces, identify objects, and perform medical tasks safely.

2.3.4 Navigation and Control

Navigation and control systems help medical robots perform their required tasks accurately. The robot uses sensor information and control algorithms to control its movement and position. Some robots are controlled directly by doctors or therapists, while others can perform specific tasks automatically. Proper control is important for improving accuracy and patient safety.

2.3.5 AI and Computer Vision

Artificial Intelligence and computer vision are increasingly used in medical robotics. AI can help in medical image analysis, object detection, patient monitoring, diagnosis support, and surgical assistance. Computer vision allows robots to identify objects, instruments, body parts, or specific areas during medical procedures.

2.3.6 Communication

Communication systems allow medical robots to exchange information with doctors, healthcare workers, and other medical devices. Wireless communication can be used for remote monitoring, patient assistance, and data transfer. In some robotic systems, communication between the robot and the operator helps doctors or therapists control the robot during medical procedures

2.3.7 Testing

Medical robots are tested using simulations, laboratory experiments, and clinical or practical testing. Surgical robots are tested for accuracy and safe movement, while rehabilitation robots are tested with exercises and patient movements. These tests help researchers evaluate the robot's performance, reliability, safety, and effectiveness.

2.3.8 Applications

Medical and healthcare robots are used for different applications such as robotic surgery, patient rehabilitation, patient monitoring, medical examination, medicine delivery, elderly care, and hospital assistance. They can help doctors and healthcare workers perform tasks with better precision and reduce physical workload.

2.3.9 Recent Developments of Medical and healthcare Robots

Recent developments in medical robotics focus on Artificial Intelligence, advanced sensors, computer vision, autonomous operation, and improved human-robot interaction. Surgical robots are becoming more precise, while rehabilitation robots are being developed for personalized patient exercises. Assistive and medicine-delivery robots are also being developed to support patients and healthcare workers.

AI-based systems are increasingly used for medical image analysis, disease detection, surgical assistance, and patient monitoring. Wearable and soft robotic systems are also being developed for rehabilitation and elderly care

2.3.10 Future scope

In the future, medical and healthcare robots are expected to be used more widely in surgery, rehabilitation, diagnosis, patient monitoring, elderly care, and hospital services. Surgical robots may provide more accurate and minimally invasive procedures. Rehabilitation robots may provide personalized exercises based on individual patient needs

Healthcare robots may also support home-based care, remote medical assistance, medicine delivery, and continuous patient monitoring. Overall, future developments will focus on making medical robots safer, more affordable, intelligent, and easier to use.

3. HUMANOID ROBOTICS

3.1 Humanoid Robot

A humanoid robot is a robot designed to have a human-like body structure, such as a head, two arms, and two legs. It is developed to perform human-like activities such as walking, talking, picking up objects, and interacting with people. It uses sensors, cameras, actuators, artificial intelligence, and control systems to perform tasks.

3.2 Types of Humanoid robots

3.2.1 AI-Driven Humanoid Robot

It's a multilingual receptionist robot for hospitals using speech recognition, NLP, Raspberry Pi & obstacle detection to assist patients and automate guidance. Purpose is to provide 24/7 personalized support, automate repetitive tasks, and improve service efficiency and accessibility.

3.2.2 Social / Anthropomorphic humanoid

It studies how a robot's human-like appearance, facial emotions, and interaction skills affect human comfort or unease - the Uncanny Valley effect. It's purpose is to balance looks and behavior to boost engagement, trust, and natural collaboration with humans.

3.2.3 Commercial / Industrial legged humanoid robot

It covers market growth from $1.5B in 2023 to $22.6B in 2030, with vendors rising from 55 in 2025 to 90 in 2026, mainly in Asia-Pacific. Purpose is to assess tech maturity and R&D directions, so companies can find niche applications and partnerships to drive adoption

3.2.4 Teleoperated / Remote-controlled

It enables a human operator to remotely control the humanoid for tasks in hazardous or inaccessible areas using gestures, voice, or controllers, while receiving real-time feedback via cameras, LIDAR, force, video/audio/haptics.

3.2.5 HRI - Humanoid

Understands human cues like speech, gestures, expressions via vision/audio/touch sensors and responds with actions, speech and adapted interaction strategies. It aims for natural, empathetic collaboration — effective HRI needs adaptability, clear communication and AI multimodal integration to boost engagement and trust.

3.2.6 Bipedal humanoid robot

It's a humanoid that walks on two legs like a human using sensors, actuators and balance control to mimic human locomotion. Used as commercial legged humanoids enables operation in human environments like stairs, factories and service areas.

3.2.7 Motion Planning (MIT) Humanoid

It's the MIT Humanoid that executes acrobatic behaviors like flips and spinning jumps using actuator-aware kino-dynamic motion planner. It uses 2 proprioceptive actuators + MPC + whole-body impulse control — planner checks torque, velocity and power limits to generate dynamic stable trajectories.

3.2.8 HOVER

HOVER is a humanoid robot designed to perform human-like movements such as walking, balancing, and interacting with its surroundings. It uses advanced sensors and motion-control systems to achieve stable, coordinated, and efficient humanoid movement.

3.2.9 Multi-Mode Versatile Humanoid

A humanoid robot designed to perform different tasks and operate in multiple modes, such as walking, running, manipulation, and human interaction. It can adapt its movements and functions according to the task or environment, making it useful in various applications.

3.2.10 Sensor Heads for Humanoid Robot

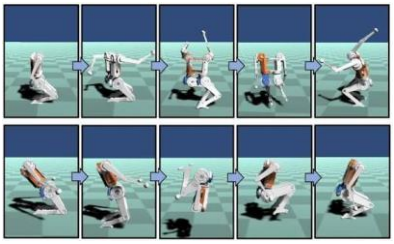
Sensor heads are the robot's sensing units, usually located in the head, that use cameras, microphones, and other sensors to perceive the environment. They help the humanoid robot recognize objects, detect people, understand sounds, and navigate safely.



(a) AI-driven humanoid



(b) Anthropomorphic humanoid



(c) Motion-planning robot



(d) Industrial legged humanoid robot



(e) Teleoperation-controlled humanoid



(f) Sensor heads for humanoid robot

Fig. 3. Examples of humanoid robots

3.3 Results and Discussion

3.3.1 Robot Design

Humanoid robots are designed with a human-like body structure, including a head, torso, arms, and legs. They combine mechanical parts, sensors, actuators, and control systems to perform human-like movements. The design focuses on balance, stability, mobility, manipulation, and safe human–robot interaction.

3.3.2 Propulsion and Movement

Humanoid robots use electric motors and actuators to generate movement in the legs, arms, and joints. They use sensors and control systems to maintain balance and coordinate walking, turning, and other movements. The propulsion system enables smooth, stable, and human-like locomotion.

3.3.3 Sensors

Sensors help the robot detect its surroundings, body position, movement, and obstacles. Common sensors include cameras, IMUs, force/torque sensors, tactile sensors, and microphones. They provide real-time information to the control system for balance, navigation, object recognition, and safe interaction.

3.3.4 Navigation and Control

Humanoid robots use sensors and cameras to detect their surroundings, locate obstacles, and determine their position. Control systems process this information to plan walking paths and coordinate the robot's joints and movements. This enables the robot to move safely, maintain balance, and reach its desired destination.

3.3.5 AI and Computer Vision

AI helps humanoid robots learn, make decisions, recognize objects, and interact intelligently with humans. Computer vision uses cameras to identify objects, people, faces, and surroundings. Together they enable the robot to understand its environment and perform tasks autonomously.

3.3.6 Communication

Communication systems allow humanoid robots to interact with humans using speech, gestures, facial expressions, and displays. They use microphones, speakers, cameras, and AI-based language processing to understand and respond to people. This enables natural human–robot interaction and information exchange.

3.3.7 Testing

Humanoid robots are tested for walking stability, balance, movement accuracy, and obstacle avoidance. Their sensors, AI, vision, and control systems are tested to ensure accurate responses. Finally, human–robot interaction and overall safety, reliability, and performance are evaluated.

3.3.8 Applications

The robots studied in these papers can be used for different humanoid activities. Humanoid robots are used in healthcare, manufacturing, education, domestic services, and customer support. They can assist humans in dangerous environments, such as disaster areas and space exploration. They are also used for research, entertainment, and human–robot interaction

3.3.9 Recent Developments of Humanoid Robots

Recent humanoid robots are becoming more autonomous, intelligent, and human-like through AI, advanced sensors, and improved actuators. They can now perform walking, object handling, speech interaction, and complex tasks with better balance and precision. Developments in generative AI, computer vision, reinforcement learning, and lightweight robotic hardware are making humanoid robots more useful in industries and everyday environments.

3.3.10 Future scope

In the future, the humanoid robotics is very promising because humanoid robots are being developed to work safely and efficiently in environments designed for humans. Future research will focus on improving artificial intelligence, human–robot interaction, mobility, manipulation, sensing, energy efficiency, and autonomous decision-making. Humanoid robots are expected to support humans in industries, healthcare, education, disaster response, domestic services, and hazardous environments. Further research will focus on improving energy efficiency, battery life, safety, reliability, affordability, and decision-making capabilities. The integration of advanced AI with whole-body control and tactile sensing may enable humanoid robots to work safely alongside humans and adapt to changing environments. Addressing challenges related to cost, cybersecurity, ethics, privacy, and public acceptance will be essential for their successful large-scale deployment. Overall, future developments in humanoid robotics have the potential to transform human–robot collaboration and create intelligent robotic systems capable of performing a wide range of real-world tasks.

4. AGRICULTURE ROBOTICS

4.1 Agriculture robot

An agricultural robot is a robotic machine designed to perform various farming activities automatically or with minimal human assistance. It is used for planting, seeding, weeding, spraying, crop monitoring, irrigation, and harvesting. It uses sensors, cameras, GPS, artificial intelligence, and control systems to improve farming efficiency and productivity.

4.2 Types of Agriculture Robotics

4.2.1 Crop and Weed Detection Robot

This type of agricultural robot uses cameras and artificial intelligence to identify crops and weeds in the field. The captured images are processed using computer vision and deep learning techniques.

4.2.2 SPARROW Weed Removal Robot

SPARROW is an autonomous agricultural robot developed mainly for weed detection and removal. It uses cameras and computer vision to identify weeds between crop rows. The robot can navigate through the field and detect the location of unwanted plants.

4.2.3 Modular 4WD Agricultural Robot

This robot uses a four-wheel-drive system to move through agricultural fields. One important feature is its modular design, which allows different tools to be attached to the robot. The robot can be used for activities such as grass cutting, leaf crushing, and precision seeding.

4.2.4 ROS-Based Unmanned Mobile Robot

This type of agricultural robot uses the Robot Operating System (ROS) to control and coordinate different robotic functions. It can use cameras and other sensors to understand its surroundings and move through agricultural areas.

4.2.5 Osiris++ Multi-Robot System

Osiris++ focuses on using robotic systems for precision agriculture and better understanding of farm environments. It can combine information from robots, sensors, and agricultural surroundings. The system can help robots understand crops, rows, objects, and other important features of a field.

4.2.6 GIS-Based Agricultural Robot Vehicle

This type of system uses GIS and remote monitoring to observe and manage agricultural robots. The location and working condition of robots can be monitored from a remote system.

4.2.7 Agricultural Harvesting Robot

Harvesting robots are designed to identify and collect agricultural products such as fruits or other crops. Cameras and sensors help the robot locate the mature crop or fruit. A robotic mechanism or end-effector is then used to pick the crop carefully.

4.2.8 Agricultural Monitoring Robot

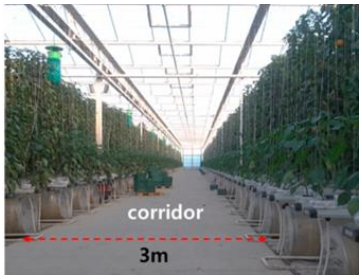
An agricultural monitoring robot is mainly used to collect information about crops and field conditions. It can use cameras and sensors to observe plant growth, crop health, soil conditions, and other field information.

4.2.9 Agricultural Seeding Robot

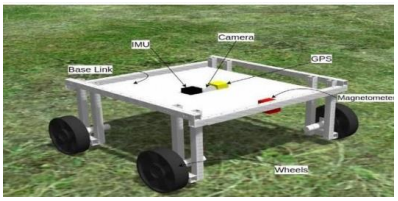
A seeding robot is designed to place seeds at suitable positions and depths in the soil. Sensors and mechanical seed-placement systems help maintain proper spacing between seeds. The robot can move through the field while performing the seeding operation.

4.2.10 Agricultural Weeding and Trimming Robot

This type of robot is designed to remove unwanted plants or trim vegetation using mechanical tools. The robot can move through crop areas and operate cutting or trimming mechanisms. Sensors or cameras can be used to identify the working area and avoid damaging useful crop.



(a) ROS-based unmanned robot



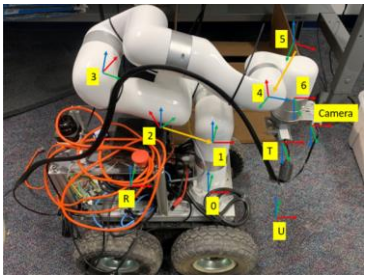
(b) Crop and weed detection robot



(c) Agricultural harvesting robot



(d) Agricultural weeding robot



(e) Agricultural monitoring robot



(f) GIS-based agricultural robot

Fig. 4. Examples of agricultural robots

4.3 Results and Discussion

4.3.1 Robot Design

Agricultural robot design focuses on making robots strong, lightweight, autonomous, and suitable for farm conditions. Different designs use 4WD or skid-steer systems, cameras, LiDAR, IMU, and other sensors for movement and navigation.

4.3.2 Propulsion and Movement

Agricultural robots use motors and wheel-drive systems to move through fields. The research papers mainly use 4WD, differential-drive, and skid-steer systems for stable movement on uneven ground and between crop rows. Sensors and navigation systems help the robot follow the planned path and avoid obstacles.

4.3.3 Sensors

Agricultural robots use cameras, LiDAR, IMU, and other sensors to understand the field and detect crops, weeds, and obstacles. Cameras provide visual information, LiDAR measures distance and obstacles, and IMU provides information about the robot's motion and orientation.

4.3.4 Navigation and Control

Agricultural robots use navigation systems and controllers to move along planned paths and stay between crop rows. Sensors such as LiDAR, cameras, and IMU provide information about the robot and its surroundings.

4.3.5 AI and Computer Vision

Agricultural robots use AI and computer vision to identify crops, weeds, and other objects in the field. Cameras capture images, and AI techniques such as deep learning and object detection process these images.

4.3.6 Communication

Agricultural robots use wireless communication and remote monitoring systems to exchange information between the robot and the operator. Communication helps in sending control commands, receiving sensor data, monitoring robot status, and tracking field operations.

4.3.7 Testing

The agricultural robots are tested through simulation, laboratory experiments, and field trials. Testing is used to check the robot's movement, navigation accuracy, sensing, task performance, and overall operation under different farming conditions.

4.3.8 Applications

Agricultural robots are used for crop monitoring, weed detection and removal, precision spraying, seeding, harvesting, cutting, and field inspection. They help farmers perform these tasks with better accuracy, less human effort, and improved efficiency.

4.3.9 Recent Developments of Agriculture Robots

Recent developments in agricultural robotics focus on AI, computer vision, autonomous navigation, advanced sensors, and modular robot designs. Robots are becoming capable of detecting weeds and crops, monitoring fields, performing precision spraying, and using different tools for tasks such as cutting, seeding, and harvesting. Multi-purpose and low-cost robots are also being developed to improve efficiency, accuracy, and automation in farming.

4.3.10 Future scope

In the future, agricultural robots can become more autonomous, intelligent, and efficient. Improvements in AI, computer vision, sensors, navigation, and communication can help robots work more accurately in different field conditions. Multi-purpose robots may perform tasks such as weeding, spraying, seeding, monitoring, and harvesting with less human effort. Future development can also focus on low-cost robots, better battery life, multi-robot cooperation, and reliable real-field operation.

CONCLUSION

The study of robotics and its emerging applications in underwater, medical and healthcare, humanoid, and agricultural fields shows that robotics is becoming an important part of modern technology. Recent research highlights the use of sensors, artificial intelligence, machine learning, computer vision, and autonomous control to improve the performance of robotic systems.

Underwater robots support ocean exploration, marine research, and underwater inspection. Medical and healthcare robots assist in surgery, rehabilitation, diagnosis, and patient care. Humanoid robots are being developed to perform human-like activities and interact with people, while agricultural robots help with planting, spraying, weeding, crop monitoring, and harvesting.

Although these technologies provide several benefits, challenges such as high development cost, energy consumption, safety, reliability, and complex control systems still need improvement. Overall, continuous research and technological advancements are expected to make robots more intelligent, accurate, reliable, and autonomous. Robotics has great potential to improve efficiency and support human activities in various fields in the future.

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